APPENDIX F.

Information for Park Rescoring of Vital Signs

Information provided to park staff for rescoring Vital Signs during the second round of the selection and prioritization process on 3/1/2004. The information briefly summarizes discussions and scoring by scientists who participated in advisory and focus groups and information from conceptual models.

Aq # = Average score from the aquatic and air resources workshop

Terr # = Average score from the terrestrial and wetlands workshop

Pk # = Average score from representatives of the nine parks

Blanks appear where scoring was not applicable for a particular group

WATER QUALITY

#1 Core water quality suite - *Measures* mandated by the Water Resources Division are temperature, conductivity, pH, dissolved oxygen, and some measure of stream flow or lake level.

<u>Ecological significance</u> *(Aq 4.5, Terr 4.6, Pk 3.9)* Both focus workshops noted the high significance of this indicator as it integrates with other data on water quality. Water levels and flow are particularly important and are covered in greater detail in indicator #14.

<u>Management significance</u> *(Pk 3.6)* Some parks designated as Outstanding Resource Waters. In enabling legislation for some parks (i.e. SLBE). Certain measures are problems for specific parks and reasons for them being listed with impaired waters under 303(d) of the Clean Water Act.

<u>Measurability/Sensitivity</u> *(Aq 4.7, Terr 4.4)* While there was no discussion about the sensitivity of the parameters to change, the groups noted that all 5 variables are relatively easy to measure. Because there will be tremendous variability both spatially and temporally, there was a lot of discussion about the frequency and cost of meaningful sampling.

#2 Advanced water quality suite - *Measures* include chlorophyll a, organic carbon, major ions, nutrients, turbidity, suspended sediments, light penetration.

<u>Ecological significance</u> *(Aq 4.7, Terr 3.6, Pk 4.1)* Significance is critical, as these parameters characterize the medium for all aquatic organisms.

<u>Management significance</u> *(Pk 3.7)* Concerns regarding influx of nutrients and sediments from runoff and tributaries.

<u>Measurability/Sensitivity</u> *(Aq 4.2, Terr 2.8)* Some of these parameters will be expensive to monitor, but standard methods exist. Ion chemistry varies little, so it would not need to be measured as often as some other parameters. Chlorophyll a is not as sensitive as expected, according to studies in Canada, but many folks still use it. Some of the parameters are sensitive to watershed disturbances.

#3 Aquatic pathogens - *Measures* include *E. coli*, fecal coliform, and cyanobacteria counts; other species may be important in the future.

<u>Ecological significance</u> *(Aq 1.9, Terr __Pk__)* These pathogens are related more to human use than to ecosystem function. The effects are often very localized.

Management significance (Pk__) This can be a significant human health risk causing beach closures in some Network parks (INDU, SLBE). Lakeshore samples are needed for community relations. Means of anticipating pulses would be desirable.

Measurability/Sensitivity (Aq 2.9, Terr__) Sampling should be conducted in areas of human use after runoff events. The measures may indicate overall land use and can be linked to the land use/land cover indicators (#12 & 13).

#4 Sediment analysis - *Measures* include nutrients, diatoms, pollen, texture (sand, silt, clay), embeddedness.

Ecological significance (Aq 4.5, Terr __, Pk 3.3) Sediments are integrative, give a picture of processes (sediment/water column exchange), and can be used for historical context.

Management significance (Pk 2.6) Dredging impacts sediment deposits on beaches and may contribute to the release of contaminants. Some species (e.g., mussels and fish) are impacted by sedimentation. See indicator #16.

Measurability/Sensitivity (Aq 3.8, Terr__) Biogenic silica is probably the best measure of overall productivity; it is measurable and sensitive to annual change.

CONTAMINANTS

#5 Trophic bioaccumulation - *Measures* could include contaminant loads in various organisms (e.g., fish, bald eagle chicks, otter, mink, snapping turtle eggs, loons, colonial waterbirds). Stable isotopes may be used to trace the origin of a contaminant.

Ecological significance (Aq 4.4, Terr 3.3, Pk 3.6) Bioaccumulation of toxics is known to impair wildlife at upper trophic levels (egg shell thinning). Fish may be the first organisms to show bioaccumulation of toxics, and lots of other organisms eat fish, hence bioaccumulation in fish has impacts across trophic levels.

Management significance (Pk 3.1) Bioaccumulation is a threat to upper trophic levels, including species of concern and humans. Fish consumption advisories reflect these health concerns and impact park visitors.

Measurability/Sensitivity (Aq 3.7, Terr 2.4) It is best to sample an organism at an intermediate trophic position (fish). Standard methods exist for measuring bioaccumulation, but such measures are expensive. Other agencies are currently monitoring this indicator so data are available.

#6 Health, growth, and reproductive success - *Measures* include percentages of organisms with tumors or percent reproductive success of organisms listed in #5.

Ecological significance (Aq 3.7, Terr 2.7, Pk 3.0) Neither Focus Group had specific comments on the ecological significance, but there are obvious species-specific implications and it could uncover systemic problems.

Management significance (Pk 2.8) May reflect wildlife and human health concerns. Tumors on fish are a management concern on the Great Lakes.

Measurability/Sensitivity (Aq 1.8, Terr 2.9) Recording incidence of lesions, tumors, or deformities can be accomplished along with other organism/community monitoring. Cause and effect would be difficult to discern.

#7 Air deposition/contaminants (changed from air quality) - *Measures* would consist of a variety of contaminants and nutrients deposited atmospherically (N, NO3, NH4, pesticides, P, Hg, S, atrazine, brominated compounds), as well as ozone.

Ecological significance *(Aq 4.0, Terr 4.1, Pk 3.0)* Significant in both aquatic and terrestrial systems. SO4 influences methylation of Hg; high N leads to declines in fungal communities; succession, susceptibility to disease, tree growth are all affected by deposition; chemical composition of leaves can change, which may lead to changes in the taste of caterpillars and avoidance by birds (hence cascading trophic effects).

Management significance *(Pk 2.1)* Ozone, mercury, and other toxics are of concern depending on the park.

Measurability/Sensitivity *(Aq 2.5, Terr 3.4)* Requires a reactive monitoring program, as it's very difficult to anticipate which of many new toxics to measure next. Monitoring is being conducted by others (e.g., NADP), so data are available.

#8 Toxic concentrations in water - *Measures* include contaminant concentrations in wastewater and surface water.

Ecological significance *(Aq 2.6, Terr__, Pk 3.0)* Toxic chemicals in water bioaccumulate in species at upper trophic levels and can impact wildlife health and reproductive success. Linked to other indicators (#6, #7, #9).

Management significance *(Pk 3.2)* Toxic concentrations in stream systems can help locate point source discharges. Private and municipal sewage disposal and boathouses are sources of concern.

Measurability/Sensitivity *(Aq 2.1, Terr __)* It is important to measure the co-factors of pH, organic C, and major ions when measuring any contaminant in water. Often contaminants are dilute in water and therefore difficult to measure. It is often better to look at organisims that bioaccumulate the toxics. This may be more of a research question, such as assessing the direct toxicity to aquatic organisms, rather than part of a monitoring program. There are high lab costs involved and lots of variability over time.

#9 Toxic concentrations in sediments (added at Air/Aquatic Worshop) - *Measures* would be the contaminant loads in sediments and interstitial porewater.

Ecological significance *(Aq 3.8, Terr__Pk__)* More significant than concentrations in water. Sediments are a reservoir for many toxics.

Management significance *(Pk__)*. Disruption of sediments can release toxics into the food web and is related to dredging and other management activities. See also indicators #4 and #8.

Measurability/Sensitivity *(Aq 3.2, Terr__Pk__)* Again, it is important to measure the co-factors of major ions, organic C, and pH. Concentrations in sediments are useful for tracking changes of inputs over time, but not for assessing direct toxic exposure.

LANDSCAPE, LAND USE CHANGE

#10 Air quality-related values (AQRVs) - *Measures* include particulates, visibility, smell and resources impacted by air quality (e.g., Ozone effects on vegetation).

Ecological significance *(Aq 1.6, Terr 1.9, Pk 3.2)* Directly affects plant and animal health including humans.

<u>Management significance</u> *(Pk 3.1)* There are mandates for class I and II airsheds. Smells and viewsheds in relation to visitor experience are issues in some parks.

<u>Measurability/Sensitivity</u> *(Aq 2.6, Terr 2.9)* Standard protocols exist (e.g., viewshed cameras, ambient monitors, plot sampling of plants). The cost is variable, but can be high, and monitoring is time consuming. Previous use of lichens may be questionable, but can be supportive of ambient monitoring.

#11 Soundscapes and light pollution (separated from AQRV at Air/Aquatic Workshop) - *Measures* include recording decibels and lumens (night skies).

<u>Ecological significance</u> *(Aq 3.3, Terr 1.4, Pk__)* Many animals depend on sound to distinguish between species, individuals, and mates, and to detect prey. There is evidence that unnatural sound and light may alter wildlife and insect movements, mating systems, and other behaviors. Photoperiod and light intensity can be important signals for physiological and behavioral changes.

<u>Management significance</u> *(Pk__)* Noise from vehicles, boats, snowmobiles, and ATVs may affect wildlife. Light can disrupt migration patterns of birds.

<u>Measurability/Sensitivity</u> *(Aq 3.0, Terr 1.6)* Remote sensing is possible thus reducing cost, but the science is not well developed and statistical properties of metrics are not well understood. Some data exist, but quality varies. Baseline data may be more important than developing a periodic monitoring program at this point.

#12 Land cover/land use coarse scale (land cover and land use combined at Air/Aquatic Workshop) (~30 meter resolution imagery) **-** *Measures* include cover type, patch size, fragmentation, edge, slope, aspect, connectivity of land/water types, human density, current & past human use (agriculture/forestry), and large-scale disturbances (fire, wind throw).

<u>Ecological significance</u> *(Aq 4.4, Terr 4.9, Pk 3.6)* Critical for assessing change in terrestrial and aquatic systems. It integrates well with other indicators and with data available from partners (EPA point/source data, SOLEC, etc).

<u>Management significance</u> *(Pk 3.4, avg of land cover coarse scale and land use coarse scale scores)* This indicator can help put parks into context. Development and urban sprawl impact parks. Measures can answer important questions such as how connectivity to adjacent habitat alters movements of native and exotic organisms.

<u>Measurability/Sensitivity</u> *(Aq 4.3, Terr 4.0)* Standard metrics exist. Road density, habitat fragmentation, and human density are examples of metrics that are sensitive to changes in some wildlife use patterns. Terrestrial group suggests limiting to four or five parameters that capture a majority of issues. There are statistical concerns about some metrics (e.g., mean patch size). The national I&M program, including a GLKN contractor (U of MN), is developing a “white paper” on this indicator.

#13 Land cover/land use fine scale (land cover and land use combined at Air/Aquatic Workshop) (~1 meter resolution imagery) **-** *Measures* would be of higher resolution and finer detail compared to the coarse scale indicator. This could include percent hardened shoreline, number of artificial structures, area (m^2) of various habitats, density of campsites, trails, roads, other facilities.

<u>Ecological significance</u> *(Aq 3.5, Terr 4.4, Pk 3.2)* Cumulative fine scale impacts may have significant impacts on watershed dynamics. The fine scale is important for understanding

migration/invasion of exotics, influences of structures (breakwaters), and human use. This indicator integrates well with other indicators (#16, #25, #42, #45, and #46).

<u>Management significance</u> *(Pk 3.6, avg of land cover fine scale and land use fine scale scores)* This indicator could provide data on many specific management concerns such as density and cumulative impacts from trails, campsites, canoe landings, boat launches, etc., and how they relate both spatially and temporally to resources such as nesting sites, den areas, etc.

<u>Measurability/Sensitivity</u> *(Aq 3.1, Terr 3.2)* Typically done less frequently than coarse scale, normally involves fieldwork and/or ground-truthing, more labor intensive, and thus more costly. Low flight aerial photography is a cost effective method of capturing fine-scale patterns and structures.

ECOSYSTEM PROCESSES

#14 Water level fluctuations - *Measures* include lake levels, stream flow and stage. Should use a benchmark and consider relative vs absolute elevation for lakes.

<u>Ecological significance</u> *(Aq 4.7, Terr 4.2, Pk 3.6)* Highly significant for both rivers and lakes. Tributaries contribute nutrients and sediments cumulatively to the main stem of rivers and knowing their contribution is important. During extreme droughts, die offs of benthic inverts and submersed vegetation occurs. Floods appear to enhance fish productivity.

<u>Management significance</u> *(Pk 2.9)* Stream flow and lake levels affect visitor use as well as fish, wildlife, and nutrient cycling. Several parks have dams that create artificial lake levels and stream flows (it's a dam issue).

<u>Measurability/Sensitivity</u> *(Aq 4.2, Terr 3.6)* Coarse data readily available (Great Lakes, USGS stream gauges), but fine scale data requires gauges and ground-based monitoring. This level of detail is not currently available in most parks. Relatively inexpensive continuous monitoring systems are available; major cost would involve initial site selection and calibration. Formal USGS stream gauge stations can cost $30k to set up and $15k/year for data and upkeep.

#15 Nutrient dynamics/biogeochemistry - *Measures* include land/water decomposition rates, microbial composition, and nitrogen, phosphorus, and carbon levels.

<u>Ecological significance</u> *(Aq 3.6, Terr 3.0, Pk 3.1)* Nutrients are linked to productivity, population dynamics, and forest health. Integrates with work done by others.

<u>Management significance</u> *(Pk 1.8)* Impacts water quality.

<u>Measurability/Sensitivity</u> *(Aq 2.3, Terr 1.7)* Carbon and nitrogen cycling is difficult (costly) to measure. Leaf litter packs (a method of measuring nutrients) are inexpensive, but require extensive repetition in the field and lab. Aquatic group considered this a research question, and noted that decomposition is sensitive to cadmium.

#16 Fluvial (riverine) geomorphology (originally called stream dynamics) - *Measures* for stream systems include rate of scouring, erosion/sedimentation, channel change, development and loss of islands, stream profile, and location of small intermittent streams, wetlands, beaver impoundments, and coarse woody debris.

<u>Ecological significance</u> *(Aq 3.9, Terr 3.4, Pk 2.9)* Critically important to stream biota and riparian habitats.

<u>*Management significance*</u> *(Pk 2.9)* Can help managers predict changes in stream course and flow and understand the effects on biota. At some parks, flow affects visitor use. Both lack of change (hardening and channelization) and natural change (stream bank erosion) can be issues. Related to indicator numbers #4, #12, #13, and #14.

<u>*Measurability/Sensitivity*</u> *(Aq 3.5, Terr 3.0)* The use of reference-reaches is easy on small streams, but costly on larger streams. Can be cost effective if aerial photography is used.

#17 Aeolian and lacustrine geomorphology (added at Terrestrial/Wetlands Workshop) - *Measures* relate to the movement of sand by wind, currents, and wave action (change in bluffs, sand spits, dunes, and other beach formations).

<u>*Ecological significance*</u> *(Aq __, Terr 3.6, Pk__)* Wind, currents, and waves alter shoreline to a large extent and affect shoreline (riparian) habitat. Can help assess human impacts and is integrative with other indicators of landscape change.

<u>*Management significance*</u> *(Pk__)* Beaches and bluffs are unique areas that provide habitat to specialized (e.g., Pitcher's thistle) and fugitive species (e.g., sand cherry, beach pea). Technical committee did not score this indicator, but see indicator numbers #12, #13, and #21.

<u>*Measurability/Sensitivity*</u> *(Aq__Terr 2.8)* Costly since it requires ground-based monitoring or high resolution imagery (LIDAR or aerial photography) but could potentially be captured under land cover/land use fine scale monitoring.

#18 Primary productivity - *Measures* of carbon fixation.

<u>*Ecological significance*</u> *(Aq 4.2, Terr 3.0, Pk 3.4)* A significant indicator of the health and function of aquatic systems including wetlands.

<u>*Management significance*</u> *(Pk 1.3)* Related to nutrient dynamics. See indicator #15.

<u>*Measurability/Sensitivity*</u> *(Aq 1.4, Terr 2.7)* Primary productivity is costly to measure directly. Better to use indirect measures such as standing biomass, secchi disk readings, diatom community structure, and dissolved oxygen. Data on primary productivity are available from the Forest Service (FIA plots) and Long Term Ecological Research (LTER) sites.

#19 Succession (forests, wetlands) - *Measure* plant growth and replacement following fire, logging, beaver activity, and other disturbances. Use models to predict vegetation trajectory to climax community.

<u>*Ecological significance*</u> *(Aq 2.4, Terr 3.8, Pk 3. 7)* A fundamental ecological process linked to primary productivity, land cover, and other indicators. This indicator would help evaluate whether vegetation is changing as predicted. Succession of beaver impoundments from forest to pond to sedge meadow has important impacts on hydrology, water quality, and other wildlife species.

<u>*Management significance*</u> *(Pk 2.9)* Stabilization of dunes, recovery from overuse and anthropogenic changes, and restoration of various habitats (e.g., beaches, oak-savannah, wetlands, and forests) may be issues at parks.

<u>*Measurability/Sensitivity*</u> *(Aq 1.7, Terr 3.4)* Would require monitoring of associated disturbances to tease out the effects (e.g., exotics and fire suppression). The terrestrial plant communities indicator may help evaluate succession, but to measure it well you would need to design a study for specific disturbances. May be costly and time consuming.

#20 Trophic relations - *Measure* rate of herbivory, predation, population change, and density using species at different trophic levels.

Ecological significance *(Aq 3.1, Terr 3.0, Pk 3.6)* The movement of energy up the trophic scale is a fundamental ecological process. This indicator could evaluate whether systems are out of balance.

Management significance *(Pk 2.6)* Deer and moose browse are of concern. Cyclical nature of prey base in aquatic and terrestrial systems impacts the entire food web. See also indicator numbers #5, #28, and #41.

Measurability/Sensitivity *(Aq 1.1, Terr 3.0)* Herbivory and population change of plants could be easily measured during other vegetation monitoring, but predation rates can be difficult, costly, and time consuming to measure depending on the species.

#21 Geological processes - *Measures* include the number and area (m^2) of major landslides, rock fall, and bluff slumping, and rebound of the Great Lakes.

Ecological significance *(Aq 2.5, Terr 2.9, PK 3.3)* closely related to #16 and #17, but the impact is generally on a larger scale and over a long period of time, though occasionally short term changes occur (e.g., rock fall, landslide).

Management significance *(Pk 3.1)* Areas prone to landslides etc. should be avoided for docks, breakwaters, and harbors. NPS mandates that ecological processes be allowed to continue. See also indicator numbers #12, #13, #16, and #17.

Measurability/Sensitivity *(Aq 2.8, Terr 3.3)*. These types of changes can be measured via remote sensing and through the use of photo points. In general, geologic processes provide background information rather than comprise a component of an ongoing monitoring effort. May be desirable to have a "rapid assessment" program to document large-scale events – both biotic and abiotic.

HABITATS

#22 Land-water transition zone - *Measures* include many parameters that describe the physical and biotic components of selected shoreline. Area of wetland, pebble beach, shrub cover etc., along with plant and animal indices.

Ecological significance *(Aq 4.1, Terr 3.5, Pk 3.6)* The land-water transition zone is a highly productive area that includes both aquatic and terrestrial systems. Related indicator numbers #12, #13, #16, #17, #39, and #46.

Management significance *(Pk 2.3)* These areas are highly visible to the public and are highly used by the public (beaches, boat launches, camping). Vulnerable to oil spills (ISRO) and other disturbances.

Measurability/Sensitivity *(Aq 3.1, Terr 3.0)* Suggest removing as an indicator - more of a sampling design issue; i.e., this is where we measure, rather than what we measure.

#23 Littoral zone (added at the Air/Aquatic Workshop) - *Measures* include the core water quality suite, plankton, aquatic vegetation, and nutrients.

Ecological significance *(Aq 4.4, Terr 3.5, Pk__)* This is a highly productive zone.

Management significance *(Pk__)* Important for fish spawning. See related indicators #22, #28 and #46.

Measurability/Sensitivity (Aq 3.7, Terr 3.5) As above, this is a sampling design issue, not an indicator. All of the measures are indicators.

#24 Soil - *Measures* include moisture, temperature, nutrients, organic matter, duff layer, compaction, degree of rutting.

Ecological significance (Aq 3.6, Terr 3.5, Pk 3.2) Soil is the foundation for all plant communities.

Management significance (Pk 1.8) Soil compaction and erosion are issues at areas of high visitor use. Impacted soils are apt to harbor exotic species. See indicator numbers #19 and #45.

Measurability/Sensitivity (Aq 3.8, Terr 2.4) The aquatics group suggested that soil is a baseline layer that should be part of the land cover/land use category. The terrestrial group suggested that soil measurements be conducted in conjunction with vegetation sampling, and not be monitored alone.

#25 Other special habitats - *Measures* would vary depending on the park. Some examples of special habitats are backwater sloughs, springs, seeps, groundwater discharge areas, dunes, clay banks, wetlands (including ridge swale wetlands), shoreline fens, bogs, and rocky shorelines.

Ecological significance (Aq 3.7, Terr 3.7,Pk 3.9) Biological diversity may be high in these areas or they are the only habitats inhabited by certain species.

Management significance (Pk 3.3) May be very important for some parks. Several of these unique areas may be especially sensitive to visitor use or changes from natural events.

Measurability/Sensitivity (Aq 2.6, Terr 3.3) Specific to the park and type of site. This indicator does not lend itself well to a broad, consistent monitoring program because the types of special habitats, and hence, the measures, protocols, and staff needs would vary widely across parks.

WEATHER AND CLIMATE

#26 Weather, meteorological data - *Measures* include temperature, precipitation, wind, storms, extreme events.

Ecological significance (Aq 4.5, Terr 4.6, Pk 4.0) These are key drivers (identified in all models) and provide context for analyzing changes in other indicators.

Management significance (Pk 2.2) Impacts visitor use and affects all resources.

Measurability/Sensitivity (Aq 4.5, Terr 4.6) Data collection can be automated. We should acquire this information from others who are already collecting it and make it readily available.

#27 Phenology - *Measures* include leaf drop, ice duration, emergence of mayflies and midges, bird arrival, frog calling, date of first killing frost, length of growing season, time of fruiting.

Ecological significance (Aq 3.6, Terr 3.9, Pk 3.6) These measures get at climate change and productivity, linked to #26.

Management significance (Pk 1.7) The impacts of global warming may impact management decisions as habitats are affected. Ice on/ice off and snowfall affects visitor use.

Measurability/Sensitivity (Aq 3.4, Terr 3.6) Some of these may be difficult to measure or interpret. On the other hand, long-term data are collected easily (and by amateurs) and can provide meaningful information. Ice duration datasets are some of the longest running.

ORGANISMS, SPECIES, POPULATIONS, COMMUNITIES

#28 Fish communities - *Measures* include species and age composition, catch per unit effort of young of the year (YOY) and adults, recruitment, and stocking rates.

Ecological significance *(Aq 4.5, Terr 3.7, Pk 3.8)* Major part of the food web, important in trophic interactions and transfer of toxics.

Management significance *(Pk 2.8)* Important harvested group in some parks. Stocking of native and non-native species is an issue for some parks. Fish consumption advisories affect visitor use and satisfaction. Refer to indicator numbers #5, #6, #8, and #44.

Measurability/Sensitivity *(Aq 3.7, Terr 3.0)* YOY are highly variable, but long-term data can explain variability. Data may be available from others (e.g., states) for data mining rather than field collection. Select a target group since monitoring the whole fish community would be difficult and expensive.

#29 IBI (Index of Biotic Integrity, reinstituted at the Air/Aquatic Workshop) - *Measures* include relative abundance, species composition (genus in some cases). IBIs can include more than just aquatic macroinvertebrates; for example an IBI can be developed using fish, and has been developed using plants (floristic quality index).

Ecological significance *(Aq 3.4, Terr__Pk__)* The aquatic group agreed that this was generally significant, while the terrestrial group thought IBIs are not very useful and preferred well-developed focus on specific communities.

Management significance *(Pk__)* This indicator was excluded by the technical committee during round 1.

Measurability/Sensitivity *(Aq 2.40, Terr__)* IBIs for streams are generally accepted, but not for lakes or wetlands. Fish IBIs are strongly sample size dependent and require several different methods. Each IBI (regardless of type) is not applicable across a variety of sites, but rather must be developed for each site. IBIs are expensive to develop, requiring a year or more to develop and test for a single stream type.

#30 Aquatic macroinvertebrates (originally benthic invertebrates) - *Measures* include species composition of overall benthic community; density of *Diporeia*, *Hexagenia*, or oligochaetes; EPT ratios (Ephemeroptera Plecoptera, Trichoptera); abundance and species composition of crayfish, sponges, *Mysis*, or odonates.

Ecological significance *(Aq 4.6, Terr 3.7, Pk 3.1)* The importance is often underestimated. The significance is high for secondary production, fish production, and nutrient cycling. See also indicator #42.

Management significance *(Pk 1.6)* Indicator of water quality.

Measurability/Sensitivity *(Aq 3.1, Terr 2.4)* Sampling is labor intensive; taxonomic expertise is required. It would be important to be consistent with state efforts; often associated with IBIs.

#31 Mussels and snails - *Measures* include species composition, density, recruitment, and distribution.

Ecological significance *(Aq 4.3, Terr__, Pk 3.2)* This is a highly threatened group whose sedentary and water siphoning behaviors make them good indicators of habitat and water quality. Often they have complex life cycles, requiring specific host species.

Management significance *(Pk 2.7)* Includes a high number of T&E species (the threat of zebra mussels on native mussels is high). See also indicator #47. This indicator is particularly important for rivers and supportive of indicators #1, #2, and #16.

Measurability/Sensitivity *(Aq 2.8, Terr__)* Methodology exists but sampling is labor intensive and often destructive of substrate. Sampling can be done infrequently (every 5yrs) to mitigate these problems.

#32 Sponges (Air/Aquatic Workshop suggested including sponges and crayfish with macroinvertebrates) - *Measures* are species composition, change in abundance.

Ecological significance *(Aq 2.3, Terr__, Pk 3.0)* Important filter feeders and can grow to large colonies in clean waters.

Management significance *(Pk 2.0)* May inhibit the spread of zebra mussels. Some pristine waters (i.e., ISRO) have large colonies.

Measurability/Sensitivity *(Aq 1.6, Terr__)* Largely unknown. The aquatic group agreed that an inventory would be worthwhile.

#33 Zooplankton - *Measures* include species composition, abundance, and changes in morphology.

Ecological significance *(Aq 4.2, Terr__, Pk 3.0)* Important prey near bottom of food web. Community composition can indicate predation pressures. Zooplankton can help interpret aquatic productivity and biomass patterns.

Management significance *(Pk 1.2)* There was little discussion at the technical committee meeting.

Measurability/Sensitivity (Aq 2.7, Terr__) Requires taxonomic expertise and can be costly; annual August sampling may be sufficient.

#34 Terrestrial invertebrate communities - *Measures* include species composition and abundance.

Ecological significance *(Aq 2.0, Terr 3.2, Pk 3.7)* Invertebrates affect decomposition rates and mycorrhizal associations. Pollinators are ecologically important and parasitoids are an important prey base.

Management significance *(Pk 2.2)* Most concerns are related to pests and exotics. See indicator #35 and 42.

Measurability/Sensitivity *(Aq 3.0, Terr 2.0)* Standard methods exist, but they are labor intensive and require taxonomic expertise.

#35 Terrestrial pathogens and invertebrate pests (new indicator from Terrestrial/Wetland Workshop) - *Measures* include rates and area of infestation of defoliators, oak wilt, Lyme disease, West Nile disease, chronic wasting disease, *Armillaria*.

Ecological significance *(Aq__,Terr 3.9, Pk__)* is potentially huge since populations of pests can explode.

Management significance *(Pk__)* Impacts health and well being of biota, including humans. Disease (Lyme disease) and infestations can impact visitor experience. Large areas of diseased forest can be fire hazards.

Measurability/Sensitivity *(Aq __, Terr 3.0)* Tree ring and remote sensing data can be used. The group did not discuss the sensitivity of this indicator.

#36 Algae (changed from phytoplankton) - *Measures* are species composition, population change, chlorophyll a.

Ecological significance *(Aq 4.1, Terr 2.7, Pk 2.9)* Primary producers at bottom of food web. Provide an index of nutrient levels, and can help interpret patterns in primary productivity. Algae are highly significant in lake systems. See also indicator numbers #2 and #15.

Management significance *(Pk 1.3)* High algal growth decreases water clarity and can reduce dissolved oxygen to toxic levels.

Measurability/Sensitivity *(Aq 2.8, Terr 2.3)* Many algae are attached (periphyton) rather than planktonic, so plankton tows will yield skewed subset of species. Diatoms in surficial sediment cores may be the best overall measure of productivity. A surface water grab in August for blue-greens and scums may be worthwhile. Because turnover is fast, counting is not feasible, is labor intensive, and taxonomic expertise is required.

#37 Diatoms (added at the Air/Aquatic Workshop) - *Measures* include species composition and density of diatoms from surficial deposits and sediment cores, which provide current and historical water quality records respectively.

Ecological significance *(Aq 4.3, Terr__, Pk__)* Cores provide a good historical perspective of water quality parameters. A single, annual surface sediment sample is integrative of the population within a lake.

Management significance *(Pk__)* The technical committee did not score this indicator. The historical context is important for management to understand the limits of natural variability and triggers for action.

Measurability/Sensitivity *(Aq 3.9, Terr__)* Diatoms are sensitive to water quality parameters and are easily measured. A change in the diatom community indicates a change in the system. Large databases exist globally for comparisons. Taxonomic expertise is required.

#38 Lichens and fungi (added at Air/Aquatic Workshop) - *Measures* are species composition and abundance.

Ecological significance *(Aq__, Terr 2.6, Pk__)* They provide an important food source, microhabitat, and are crucial in many mycorrhizal associations.

Management significance *(Pk__)* The technical committee did not score, but lichens were suggested as indicators of air quality at scoping sessions.

Measurability/Sensitivity *(Aq__, Terr 1.9)* Standard methods exist but they are time consuming and require taxonomic expertise.

#39 Amphibians and reptiles (herptiles) - *Measures* include species composition, population change, habitat distribution, percent deformities, number of egg masses. Snapping turtle eggs are good indicators of toxics.

Ecological significance *(Aq 3.8, Terr 3.9, Pk 4.1)* Major vertebrate group that drives many food webs and has high biomass. Good integrator of aquatic and terrestrial ecosystems. See also indicator #47.

Management significance *(Pk 2.9)* Some parks referenced direct management decisions relative to T&E species (INDU). Turtle nests sometimes need protection.

Measurability/Sensitivity *(Aq 2.6, Terr 3.0)* Sensitive to habitat loss, drought, habitat condition, toxins, Ultra-Violet light, fish stocking, and parasites. Many standard methods exist (call surveys, drift fences, cover boards), but some need to be evaluated for accuracy and some are labor intensive. Timing of monitoring is critical. Call surveys are of questionable value because of a high signal to noise ratio. The Natural Resource Research Institute is currently evaluating this indicator.

#40 Bird communities - *Measures* include species composition, distance to individuals (for density estimates), population change, young produced/occupied area (productivity).

<u>*Ecological significance*</u> *(Aq 3.6, Terr 3.9, Pk 4.2)* Birds account for high biotic diversity (60-65 percent of vertebrates), and contribute to seed dispersal and the control of pest populations. They are also disease vectors and spread exotic plants and animals. Some corridors (Mississippi and St. Croix rivers and Great Lakes shorelines) act as major flyways so that measures of bird use can represent species abundance across large regions. May be indicators of habitat change. Presence/absence of certain diving ducks can indicate changes in food sources. Birds are mid- to high-level bioaccumulators, and integrate aquatic and terrestrial environments.

<u>*Management significance*</u> *(Pk 3.6)* Birds are of high interest to the public (charismatic fauna). Several species are T&E or otherwise of special concern. Neotropical migrants, grassland birds, and shorebirds are groups of special concern.

<u>*Measurability/Sensitivity*</u> *(Aq 4.0, Terr 3.4)* Standard methods exist (BBS, point, and distance counts for land birds, aerial surveys for eagles and waterfowl, boat surveys for loons) and there are abundant baseline datasets. Fieldwork can be labor intensive and is best done by the same observer(s) each year. Observers must be accomplished at identifying birds by sight and sound and need to collect habitat data. Equipment needs are minimal. Shorebirds are sensitive to shoreline development. Certain species are sensitive to habitat change though it can take many years to tease out variability.

#41 Mammal communities - *Measures* would include species composition, population size, and demographics.

<u>*Ecological significance*</u> *(Aq 3.8, Terr 3.2, Pk 3.3)* Small mammals are prey base for higher trophic levels and cyclic abundance can have a boom and bust effect on other organisms (e.g., microtine cycles can drive raptor and some mesocarnivore populations). Small mammals are seed dispersers and disease vectors. High level carnivores can effect prey abundance, demographics, and composition (i.e., wolves on white-tailed deer or moose). Beaver, as a keystone species, alter the landscape. River otter, mink, and muskrat bioaccumulate toxins and are known indicators of contaminants.

<u>*Management significance*</u> *(Pk 2.7)* Hunting and trapping can be issues in lakeshores and riverways. Mammals can be of high public interest and as such can serve to focus attention on ecological problems. For problem and T&E species, see indicator numbers #43 and #47.

<u>*Measurability/Sensitivity*</u> *(Aq 3.4, Terr 2.7)* Many standard methods exist including mark recapture, DNA sequencing, aerial surveys (beaver, moose, wolf), and tracking or sign indices. Hair samples can be used for Hg and other heavy metal analysis. Many datasets exist, both for contaminant studies and for general population studies, for comparison purposes. State agencies monitor some populations but rarely with sufficient intensity to assess park populations.

#42 Plant and animal exotics/invasives (split from problem species at the Air/Aquatic Workshop. Note park scores are included in problem species, #43) - *Measures include* distribution and abundance, surveillance and early detection, results and consequences of control efforts.

Ecological significance *(Aq 4.7, Terr 4.9, Pk__)* Some species have huge impacts, such as zebra mussels and purple loosestrife. They can alter trophic relations, change biological diversity, threaten native biota, and alter water quality. Some are highly integrative (e.g., exotic salmonids contribute large quantities of biomass as they move upstream and die). Domestic dogs and cats can negatively impact wild canid and bird populations, respectively.

Management significance *(Pk__)* Of high interest to managers. EPMT formed in response to management concerns. There are specific NPS mandates to manage exotic species.

Measurability/Sensitivity *(Aq 3.9, Terr 3.6)* Other groups (state DNR, FWS) are monitoring exotics, so some data are already available. Good protocols exist for most species. Remote sensing techniques are applicable in some cases. Monitoring of plants could be coordinated with EPMT or done in tandem with a plant community monitoring protocol. A surveillance/advance warning system could be implemented via visitor participation.

#43 Native species out of balance (previously titled problem species) - *Measure* abundance, demographics, herbivory and predation rates for species such as stocked native fish, white-tailed deer, raccoons, skunks, aquatic macrophytes, and algae.

Ecological significance *(Aq 2.8, Terr 3.9, Pk 4.3)* White-tailed deer can have chronic impacts on vegetation leading to the alteration of the composition and structure of forests. Deer can also have huge impacts on certain threatened, endangered, and sensitive species. Stocking native fish species alters the gene pool and can disrupt movements and behaviors of local stock. Excessive growth of aquatic macrophytes can alter habitat and choke waterways. Algal blooms can alter water quality for fish and other species.

Management significance *(Pk 4.4)* Closely tied to ecological significance (e.g., deer browse has impacted management decisions).

Measurability/Sensitivity *(Aq 2.9, Terr 3.1)* Methods for measuring these species are highly variable. Some are relatively easy and standard protocols exist. Aquatic macrophytes and algal blooms are sensitive indicators of nutrient enrichment and eutrophication.

#44 Harvested species - *Measure* population change, numbers or biomass harvested for species such as fish, turtles, game birds, bear, deer, furbearers, timber, medicinal and edible plants.

Ecological significance *(Aq 4.0, Terr 2.8, Pk 2.9)* Impacts of harvested species on ecosystem are not well studied or understood, but can be huge. Local over-harvest can affect recruitment and population dynamics.

Management significance *(Pk 3.2)* Fishing is a major draw of visitors to parks, and as such, has huge impacts. Harvest of animals outside park boundaries can impact park biota. Treaty rights (hunting, fishing, ricing) can be issues in certain parks. Information can be important for asserting management concerns and responsibilities with state DNRs and tribes.

Measurability/Sensitivity *(Aq 3.2, Terr 2.7)* State agencies monitor most harvested species, but estimates are rarely accurate for park populations. Harvest of migratory waterfowl is not indicative of local population change. Turtles are rarely monitored. Methods of monitoring fish harvest have known biases in less sampled areas (parks).

#45 Terrestrial plant communities - *Measures* include floristic, structural, and age composition; amount of coarse woody debris.

Ecological significance *(Aq__, Terr 4.4, Pk 4.1)* Plant communities are the key habitat component and the functional basis for terrestrial ecosystems. As primary producers they are important conveyors of energy. Plants can be used to identify special habitats and are integrative with indicators #12, #13, #18, #19, #23, #25, #39, #41, #43, and #44).

Management significance *(Pk 3.8)* Often requires cooperation with other agencies for forest health monitoring, control of exotics, and fire management. Visitor use can impact vegetation.

Measurability/Sensitivity *(Aq__Terr 3.6__)* Standard techniques are available, both on the ground and remote, but they can be time consuming and require taxonomic expertise.

#46 Aquatic and wetland plant communities - *Measures* include species composition, area of cover, structure, distribution.

Ecological significance *(Aq 4.4, Terr 4.6, Pk 3.8)* Plant communities are the key habitat component and the functional basis of aquatic/wetland ecosystems. They provide substrate, habitat, and structure; help to stabilize the substrate and prevent the spread of exotics; and are highly productive micro environments.

Management significance *(Pk 2.6)* Concerns regarding loss or degradation of wetlands and littoral areas due to water level fluctuations, development, and visitor use. Tied to indicator numbers: #13, #14, #28, #42, and #47.

Measurability/Sensitivity *(Aq 3.4, Terr 3.6)* Aquatic plants are sensitive to water quality, lake level fluctuations, climate warming, and drought. Emergent vegetation cover can be monitored remotely and hydroacoustics are beginning to be used for mapping submergents. Standard protocols are developed at different scales. Monitoring can be time consuming.

#47 T&E species - *Measures* include area, numbers, vigor, percent of biota, community composition.

Ecological significance *(Aq 3.9, Terr 2.7, Pk 3.7)* T&E species contribute to biodiversity.

Management significance *(Pk 4.6)* Parks may be islands for maintaining some of these species. The overall significance varies by species.

Measurability/Sensitivity *(Aq 2.3, Terr 2.1)* These species may be sensitive to changes in their particular habitat, though often they are difficult to find and monitor, and small sample sizes make statistical analysis difficult. Monitoring would have to be tailored to individual parks and may not be efficient at the Network level.

#48 Biotic diversity - *Measure* the total number of species, often for defined taxonomic groups such as "vascular and nonvascular plants") per unit area.

Ecological significance *(Aq 1.8, Terr 2.1, Pk 3.9)* Native biodiversity is important, and high diversity can indicate a functional ecosystem.

Management significance *(Pk 2.7)* Important areas can be targeted for protection.

Measurability/Sensitivity *(Aq 1.3, Terr 2.6)* Diversity as a measure is not very useful. Unless an IBI is developed, each species (including each exotic) is equally important. Due to issues of scale, diversity may be difficult and costly to measure and interpret. Diversity is important, but not necessarily a sensitive indicator and it can be derived from other measures.